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# **Human Factors Engineering**

***for the Face-to-Face meeting of the  
DOE Federal Technical Capability Panel  
March 29, 2011***

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## *Introduction*



“As technologies mature and become more reliable overall, the source of accidents often shifts from being hardware-related to interface-related. The discipline of ergonomics, or human factors engineering, seeks to address human characteristics, capabilities, and limitations and reflect them in the design of the things we create to make them easier to use, more reliable, and safer.”

– Steven Casey, Prologue to *The Atomic Chef* (2006)



The harder it is to do something, the less likely someone will do it effectively.....



Photographs courtesy of  
[www.baddesigns.com](http://www.baddesigns.com)

*So, how do we make it easier for people to do the right thing?*



# *Introduction*



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## **Learning Objectives**

**Audience will be able to:**

- **Define or describe Human Factors Engineering (HFE)**
- **Identify the benefits of HFE**
- **Describe HFE applicability to DOE**



# *A Definition of Human Factors*

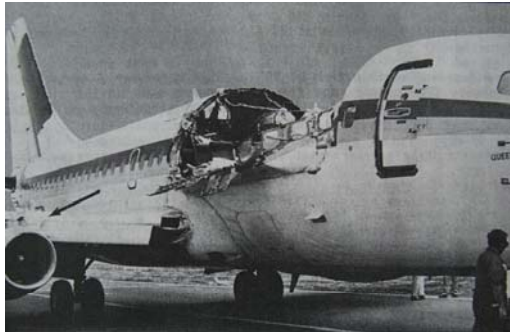


A discipline that discovers and applies information about human behavior, abilities, limitations and other characteristics to the **design of tools, machines, systems, tasks, jobs, and environments** for productive, safe, comfortable and effective human use.

(Chapanis, 1985)



## *HFE-related events*



Aloha Airlines Accident, 1998



WWII Era Cockpit Design, 1940s



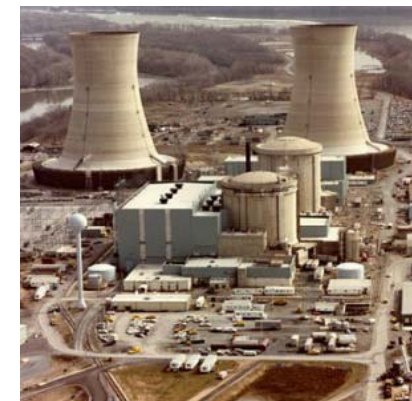
Medication Error for Dennis Quaid's Twins, 2007



DC-10 Accident, 1972



Herald of Free Enterprise, 1984



Three Mile Island, 1979



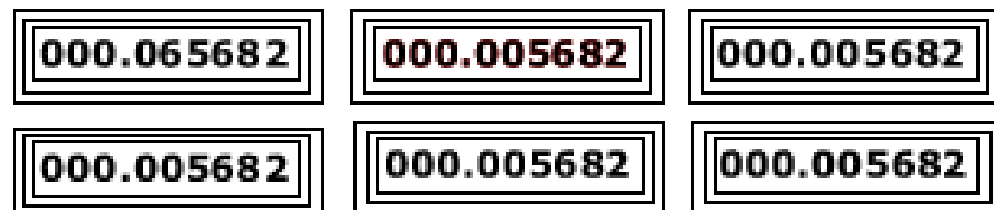
# *A Classic Human Factors Design Problem*



**Photograph courtesy of [www.baddesigns.com](http://www.baddesigns.com)**



# *The Impact of Display Design*





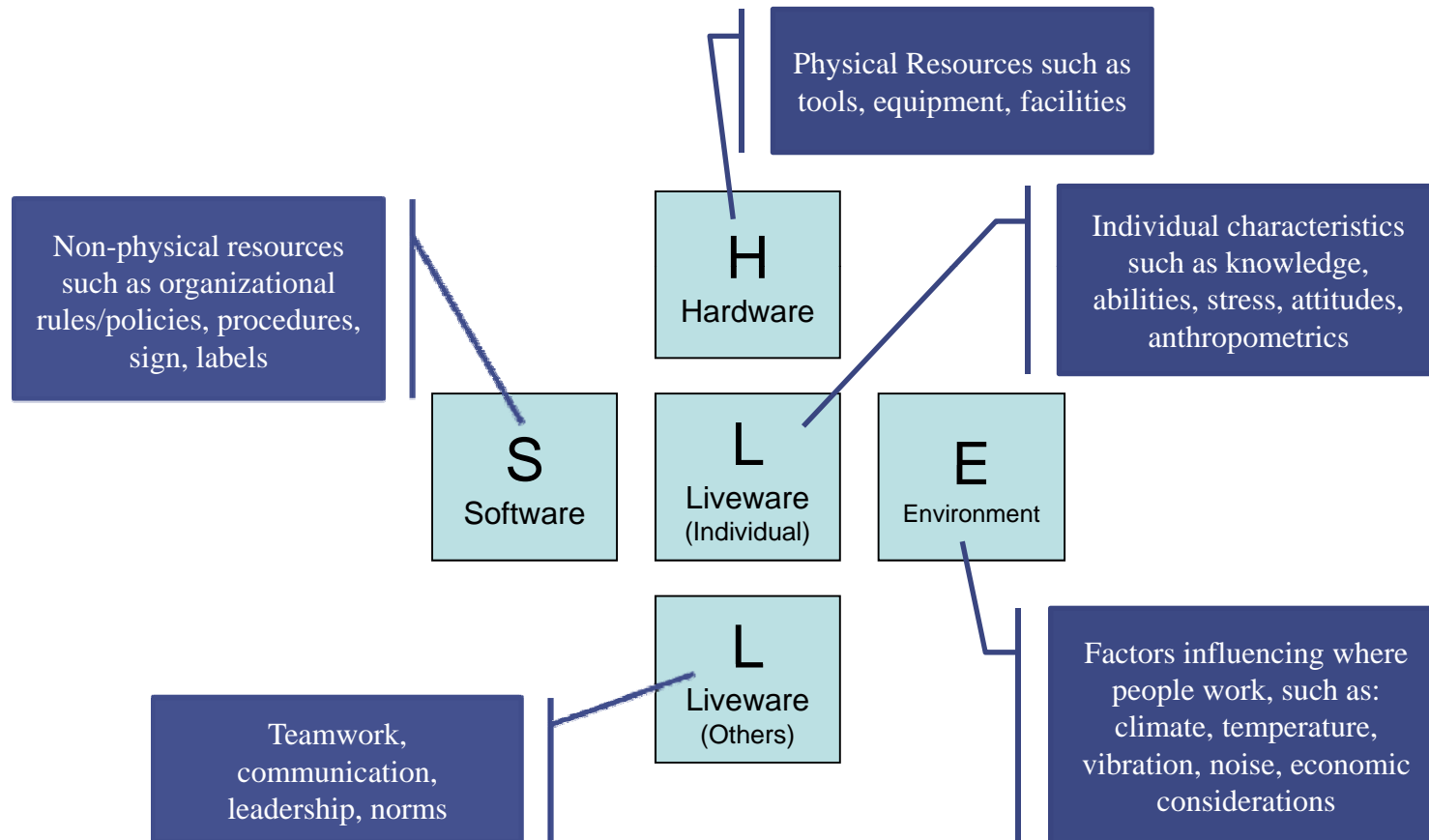


# *The Impact of Physical Workload*





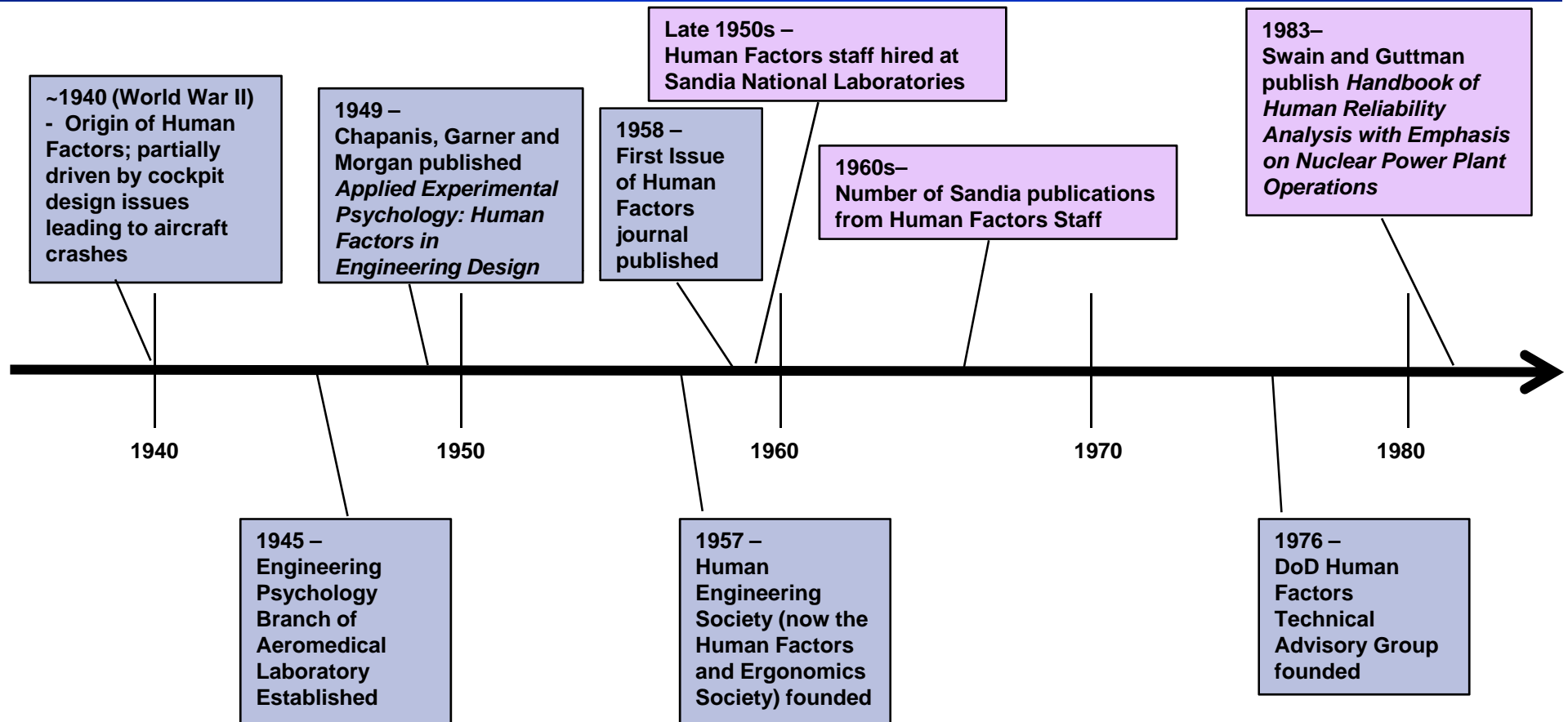
# *The SHELL Model of Human Factors*



**SHELL Model (Hawkins, 1976)**



## *Some milestones in the 60+ year history of human factors*





# *Current Status of Human Factors as a Technical Discipline*



- **HFES has more than 4500 members, and 23 technical groups**
  - » ~70% of members hold doctoral or masters degrees
  - » ~15% of members hold bachelors
  - » ~15% are students

<i>Aerospace Systems</i>	<i>Individual Differences</i>
<i>Aging</i>	<i>Industrial Ergonomics</i>
<i>Augmented Cognition</i>	<i>Internet</i>
<i>Cognitive Engineering and</i>	<i>Macroergonomics</i>
<i>Decision Making</i>	<i>Perception and Performance</i>
<i>Communications</i>	<i>Product Design</i>
<i>Computer Systems</i>	<i>Safety</i>
<i>Education</i>	<i>Surface Transportation</i>
<i>Environmental Design</i>	<i>System Development</i>
<i>Forensics</i>	<i>Test and Evaluation</i>
<i>Health Care</i>	<i>Training</i>
<i>Human Performance Modeling</i>	<i>Virtual Environments</i>



# *Current Status of Human Factors as a Technical Discipline*



- **HFES Website currently lists 70 Human Factors/Ergonomics Graduate Programs in the US (Primarily in Psychology or Industrial Engineering)**
  - » HF is still primarily a graduate level degree
  - » Only 14 undergraduate programs listed





## *Human Factors at Sandia (2011)*



- **Seven full-time HF Engineers, supporting NW, WFO and Sandia infrastructure programs throughout the life-cycle of projects/programs [5 PhD, 2 MS]**
  - » Early involvement
    - Task analysis
    - Human reliability analysis
    - Design of systems, processes and procedures
    - Research and Development (literature searches, experiments, publications, etc.)
  - » Intermediate or Iterative involvement
    - Review of system designs, processes, and procedures
    - User acceptance/usability testing
  - » Late involvement
    - Root Cause or other retrospective analysis
  - » Other
    - Human Factors Training
- **Cognitive Systems & Technology (CS&T) Research and Development Program**





# *Why do we care about Human Factors Engineering?*



- **Human involvement can introduce hazards into engineered systems**
- **The controls we employ to protect us against other hazards often rely on human performance**
- **Human error can result in impacts to safety, security, quality, reliability, productivity....**





## *Some recent DOE occurrences...*



- **Steam Plant tripped off-line because emergency stop button inadvertently depressed.**
  - » The initiating factor for the unplanned shutdown has been attributed to poor placement of one of the emergency shutdown pushbuttons in the main ingress/egress path.
- **Control room operator erroneously initiated process material transfer from evaporator to receipt tank by improperly selecting Lift Gang Valve (prime mover) on distributed control system (DCS) display in lieu of the Lance Gang Valve.**
  - » Prior to the error, operator had pulled the transfer procedure and informally verified that the plant was ready to support the transfer, however, the transfer procedure had not been completed. Upon completion of the transfer procedure review, (incorrect) Lift Gang Valve still displayed on the DCS.
- **Two plumbers were removing the coupling from what they believed to be a depressurized and drained fire sprinkler water supply pipeline. As they loosened the two bolts on the pipe coupling, hydraulic fluid under pressure sprayed out.**
  - » The pipeline from which they were removing the coupling was actually a hydraulic fluid supply pipeline for a nearby elevator. Both the fire sprinkler water supply and hydraulic fluid supply pipelines and couplings were identical, unlabeled, and were adjacent to each other.





# *HFE in the Federal Government Today*



- **DoD, FAA, and NASA [HF Technical Advisory Group (TAG)]**
  - » Working together to share best practices and improve consistency and quality of HF standards across their agencies
- **Nuclear Regulatory Commission (NRC)**
  - » Faces the challenge of certifying designs today for nuclear power plants to be built in 15 years, when control rooms (including technologies and the corresponding human use of them) will be different from what we know.
  - » Human-System Interface Design Review Guidelines (NUREG-0700, rev 2), prepared by J. O'Hara and W. Brown (Brookhaven National Laboratory) and P. Lewis and J. Persensky (NRC).
  - » Human Factors Engineering Program Review Model (NUREG-0711, rev 2) used by NRC staff to review the 12 elements of an HFE program, to verify that accepted HFE practices and guidelines are incorporated into the applicant's HFE program



# *HFE in the Federal Government Today*



- **NRC**
  - » <http://www.nrc.gov/reactors/operating/ops-experience/human-factors.html>
  - » <http://www.nrc.gov/about-nrc/organization/resfuncdesc.html#dra>
- **Department of Homeland Security**
  - » [http://www.dhs.gov/xabout/structure/gc\\_1224537081868.shtm](http://www.dhs.gov/xabout/structure/gc_1224537081868.shtm)
- **NASA**
  - » <http://human-factors.arc.nasa.gov/>
- **Department of Transportation**
  - » Federal Highway Administration
    - <http://www.fhwa.dot.gov/research/topics/safety/humanfactors/>
  - » Federal Railroad Administration
    - <http://www.fra.dot.gov/rpd/policy/1910.shtml>
  - » National Highway Transportation Safety Administration
    - <http://www.volpe.dot.gov/hf/index.html>
  - » Federal Aviation Administration
    - <https://www2.hf.faa.gov/HFPortalnew/>



## *HFE in the US Military Today*



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**“Regardless of the sophistication of Air Force systems, optimized total systems performance is contingent upon the warfighter’s ability to use systems fully and effectively to accomplish the mission. Human Systems Integration (HSI) is the vital link that optimizes the design of systems to achieve total system performance, maximizing human capabilities and overcoming human limitations.”**

**USAF FY09 Human Systems Integration Management Plan**



# *HFE in the US Military Today*



- **DoD Human Factors Engineering Technical Advisory Group (HFE TAG)**
  - » <http://www.hfetag.com/index.html>
- **Assistant Secretary of Defense for Research and Engineering: Human Performance, Training and Bio-Systems, Human Systems Integration**
  - » <http://www.dtic.mil/biosys/hsi.html>
- **U.S. Army: Human Research and Engineering**
  - » <http://www.arl.army.mil/www/default.cfm?page=31>
- **U.S. Air Force: Human Effectiveness Directorate**
  - » <http://www.wpafb.af.mil/afrl/711hpw/index.asp>
  - » <http://www.afsc.af.mil/organizations/index.asp>
- **US Coast Guard: Human Factors Engineering and Organizational Behavior**
  - » <http://www.uscg.mil/hq/cg5/cg5211/hof.asp>
- **U.S. Navy: Office of Naval Research: Human Systems Integration Division and Human & Bioengineered Systems**
  - » <http://www.onr.navy.mil/Science-Technology/Departments/Code-34/All-Programs/warfighter-protection-applications-342/Human-Systems-Integration.aspx>
  - » <http://www.onr.navy.mil/Science-Technology/Departments/Code-34/All-Programs/human-bioengineered-systems-341.aspx>



## *Sample of Existing HFE Standards*



- **MIL-STD-1472F: DoD Design Criteria Standard – Human Engineering**
- **MIL-HDBK-759C: DoD Handbook – Handbook for Human Engineering Design Guidelines**
- **MIL-HDBK-46855A: Human Engineering Program Process and Procedures**
- **FAA’s Human Factors Design Standard (HF-STD-001)**
- **ISO 11064: Ergonomic Design of Control Centres**
- **ISO 10075-3:2004: Ergonomics Principles related to Mental Workload – Part 3: Principles and Requirements Concerning Methods for Measuring and Assessing Mental Workload**
- **ISO/PAS 18152:2003: Ergonomics of Human-System Interaction – Specification for the Process Assessment of Human-System Issues**
- **NUREG-0800: Human Factors Engineering**
- **NUREG-0700: Human System Interface Design Review Guidelines**
- **ANSI/ISA 84: Safety Instrumented Systems for the Process Industry Sector**
- **ANSI/ISA 18.2: Management of Alarm Systems for the Process Industries**



## *Current DOE HFE Requirements*



- **We do have DOE requirements that address human factors....**
  - » DOE O 420.1 Facility Safety
  - » DOE O 422.1 Conduct of Operations
  - » DOE G 420.1-1 Nonreactor Nuclear Safety Design Criteria and Explosives Safety Criteria Guide
  - » DOE-STD-1186-2004 Specific Administrative Controls
  - » DOE-STD-1189-2008 Integration of Safety in the Design Process
  - » DOE-STD-3009-94 Preparation Guide for U.S. DOE Nonreactor Nuclear Facility Documented Safety Analyses
  - » DOE-STD-3024-98 Content of System Design Descriptions, § 3.2.6
  - » DOE-HDBK-1140-2001 Human Factors/Ergonomics Handbook for the Design for Ease of Maintenance



## *So what's in it for me?*



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**We know a significant amount of human performance and human limitations, and this knowledge can be used to design systems that support – rather than hinder – human performance.**

**The involvement of HFE experts on Integrated Project Teams *early in the design process* should contribute to safer, more cost-effective nuclear facility operations.**



## *Conclusions*



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### **Human Factors Engineering (HFE):**

- **Is a technical discipline with a long history and a broad scope**
- **Can confer safety, efficiency, quality, and reliability benefits**
- **Can be applied throughout the lifecycle of a system, process, or procedure**
- **Has the opportunity to be more fully leveraged in DOE**

**Remember our goal:**

**Make it easier for people to do the right thing.**





## *Additional HFE Resources*



- HFE Training at Sandia (1-day class)
- Recommended Reading
  - » *Set Phasers on Stun* (1998) and/or *The Atomic Chef* (2006) by Steven Casey
  - » *The Checklist Manifesto* (2009) by Atal Gawande
- On-line training:
  - » FAA: <http://www.hf.faa.gov/Webtraining/index.htm>
  - » NASA: <http://human-factors.arc.nasa.gov/web/humanfactors101/lessons.html>
  - » VA: <http://www.patientsafety.gov/curriculum/HFE/index.html>
- Online resources:
  - » <http://www.usability.gov>
  - » <http://www.hfes.org>
  - » <http://www.hse.gov.uk/humanfactors/index.htm>



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# BACKUP



# *Why do we care about Human Factors Engineering?*



- The design of engineered systems can influence human performance -- positively or negatively
- Installation of Center High-Mounted stop Lamps in 2,100 Washington, D.C.-area taxicabs resulted in 50% reduction in both rear-end collisions and collision severity

Based on analyses of actual data, when all cars are CHML equipped,

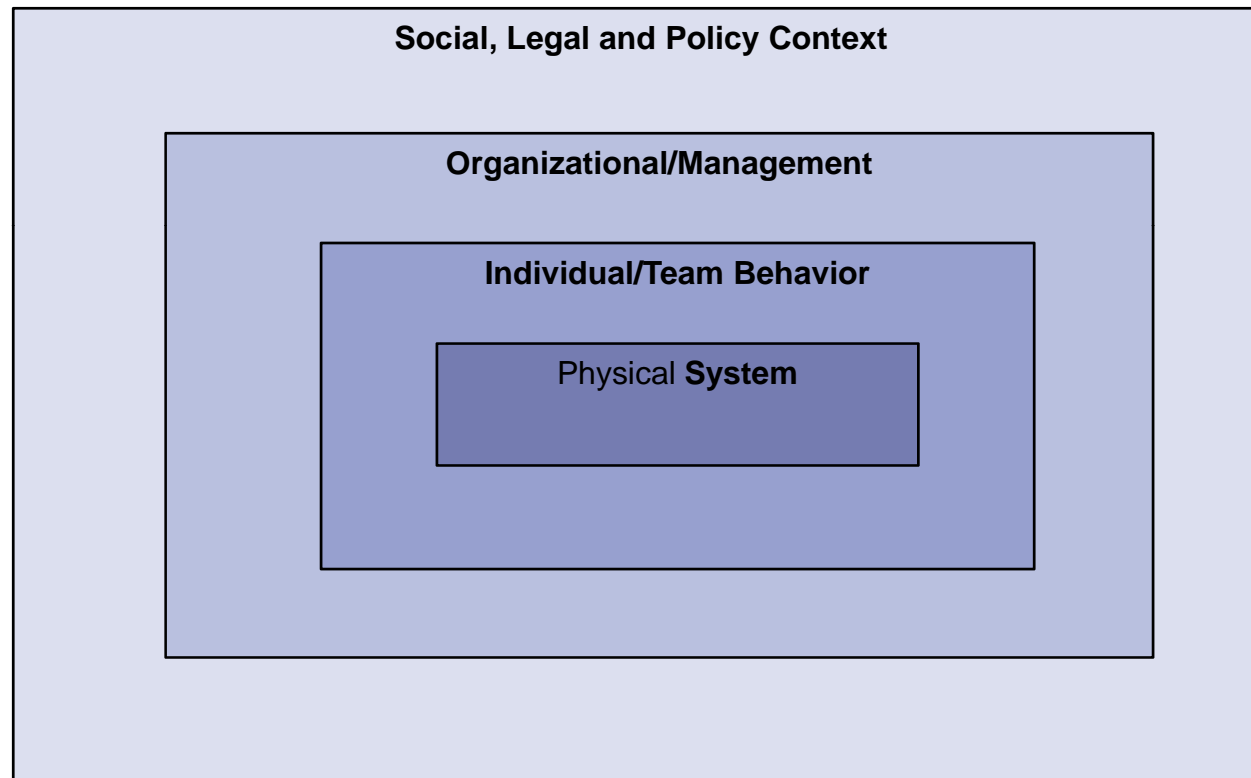
- 126,000 crashes avoided annually
- Property damage savings of **\$910 million** per year.
- Additional savings in medical costs
- The total cost of research program and regulatory program: \$5 million

A **\$5 million dollar investment** for a projected **\$910 million annual return**: not a bad ergonomics investment by the federal government!

-- “Good Ergonomics is Good Economics”, Hendrik, 1996



## *Another approach: A socio-technical perspective to HFE*



**(based on Moray, 1988)**